

## Topic 5: Alkenes

Related topics in Units 2, 4 and 5 will assume knowledge of this material.

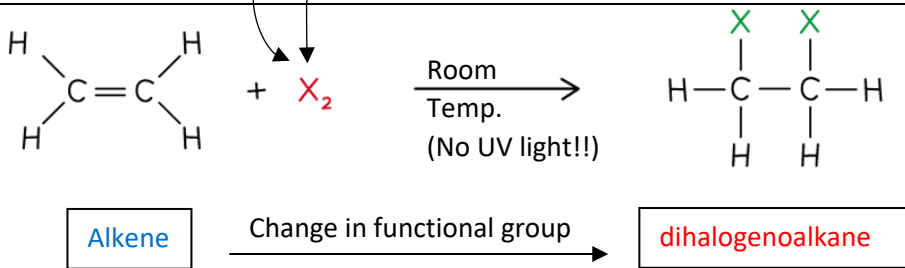
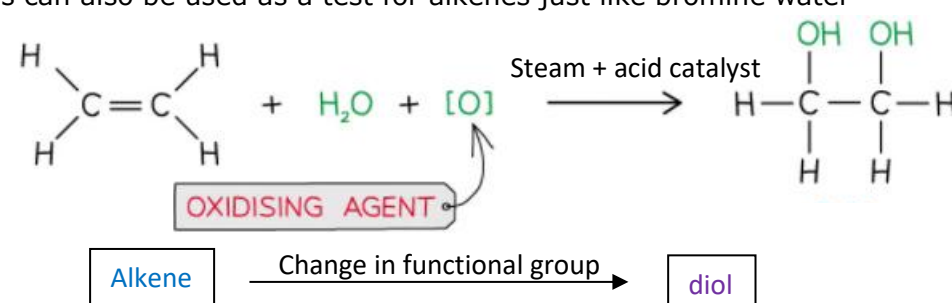
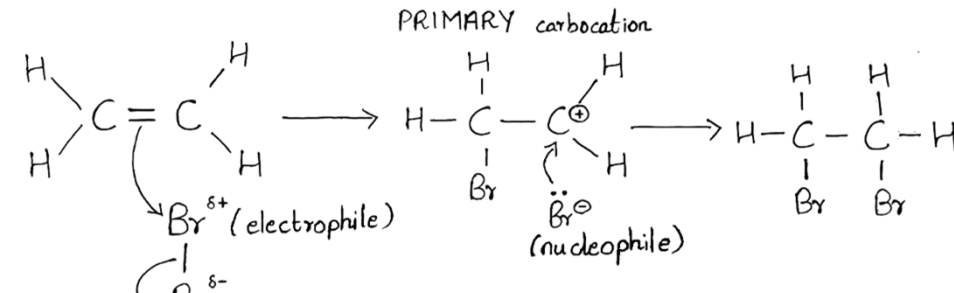
**Students will be assessed on their ability to:**

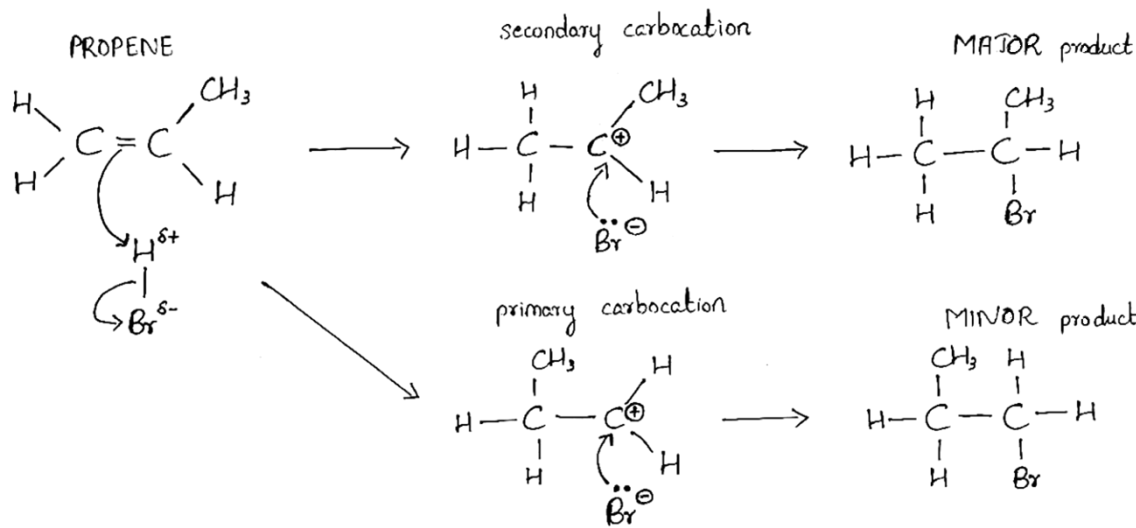
5.1	<p>know the general formula of alkenes and understand that alkenes and cycloalkenes are hydrocarbons which are unsaturated (have a carbon-carbon double bond which consists of a <math>\sigma</math> bond and a <math>\pi</math> bond)</p>
	<p>All <b>alkenes</b> contain a C=C double bond so they are all unsaturated compounds</p> <p>General Formula: <math>\text{C}_n\text{H}_{2n}</math></p> <p>The fact that they contain a C=C bond means they are more reactive than <b>alkanes</b></p> <p>Cycloalkenes have the general formula <math>\text{C}_n\text{H}_{2n-2}</math></p> <p>When forming a covalent bond, the orbitals overlap in such a way to form two types of bonds: sigma and pi bonds</p> <p><math>\pi</math> bonds (a.k.a C=C double bonds) are exposed and have high electron density hence they are more vulnerable to attack by electrophiles (electron-loving species)</p> <div data-bbox="906 645 1331 1003"> </div> <p><u>Formation of a (<math>\sigma</math>) sigma bond</u></p> <div data-bbox="418 1043 1200 1227"> </div> <ul style="list-style-type: none"> <li>- Sigma bonds are formed from the end to end overlap of atomic orbitals (this is true for both s and p orbitals)</li> <li>- Rotation can occur around a sigma bond</li> </ul> <p><u>Formation of a (<math>\pi</math>) pi bond</u></p> <div data-bbox="376 1384 1133 1657"> </div> <ul style="list-style-type: none"> <li>- <i>Pi bonds are formed from the sideways overlap of adjacent p orbitals</i></li> <li>- A single pi bond has two-electron clouds, one above and one under the plane of the sigma bond (each electron cloud representing one bond containing two electrons)</li> <li>- This arrangement maximises the overlap of the p-orbitals</li> </ul>
5.2	<p>be able to explain geometric isomerism in terms of restricted rotation around a C=C double bond and the nature of the substituents on the carbon atoms</p>
	<p>In saturated compounds, the atoms/functional groups attached to the single, <math>\sigma</math>-bonded carbons are not fixed in their position due to the free rotation about the C-C <math>\sigma</math>-bond</p> <p>In unsaturated compounds, the groups attached to the C=C carbons can only be in one of two positions, and they remain fixed in that position</p>

	<p>For compound A and B to be geometric isomers, There must be two different atoms or group of atoms on each carbon of the double bond and there is restricted rotation about the double (C=C) bond This means each geometric isomer has different physical and chemical properties</p>
<b>5.3</b>	<p>understand the <i>E-Z</i> naming system for geometric isomers and why it is necessary to use this when the <i>cis-</i> and <i>trans-</i> naming system breaks down</p>
<div>E = Trans Z = Cis</div>	<p><i>Cis-</i> and <i>trans-</i> naming system can only be used when we have only one functional group (or atom) on each side of the C=C double bond</p> <ul style="list-style-type: none"> <li>- If we have more than one, the <i>E-Z</i> naming system has to be used:</li> <li>- <i>Priority is decided by which atom has the higher atomic number</i></li> <li>- If both atoms are above or below the double bond, then it is a Z-isomer</li> <li>- If one is above and one below, then it is an E-isomer</li> </ul>
<b>5.4</b>	<p>be able to describe the reactions of alkenes, limited to:</p> <ol style="list-style-type: none"> <li>the addition of hydrogen, using a nickel catalyst, to form an alkane</li> <li>the addition of steam, in the presence of an acid catalyst, to produce alcohols</li> <li>the addition of hydrogen halides to produce mono-substituted halogenoalkanes</li> <li>the addition of halogens to produce a di-substituted halogenoalkane</li> <li>oxidation of the double bond by acidified potassium manganate(VII) to produce a diol</li> </ol>
<div>This is also a reduction reaction in terms of electron transfer</div> <div>Extensively used in manufacture of margarine</div>	<p><b>i</b></p> <p>An electrophilic addition reaction is the addition of an electrophile to a double bond (this includes all the reactions from i to iv) As stated above, the <math>\pi</math> bonds in alkenes are areas with high electron density and the fact that a <math>\pi</math> bond is weaker than a <math>\sigma</math> bond so less energy is needed to break <math>\pi</math> bond means it is more vulnerable (susceptible/ accessible) to electrophilic attack by electrophiles</p> <div> <p style="text-align: center;"> <math display="block">\begin{array}{c} \text{H} &amp; &amp; \text{H} \\ &amp; \diagdown &amp; / \\ &amp; \text{C} = \text{C} \\ &amp; / &amp; \diagdown \\ \text{H} &amp; &amp; \text{H} \end{array} + \text{H}_2 \xrightarrow[\text{HEAT}]{\text{Pt/Ni CATALYST}} \begin{array}{c} \text{H} &amp; \text{H} \\   &amp;   \\ \text{H}-\text{C} &amp; -\text{C}-\text{H} \\   &amp;   \\ \text{H} &amp; \text{H} \end{array}</math> </p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px; text-align: center;">Alkene</div> <div style="text-align: center;">Change in functional group →</div> <div style="border: 1px solid black; padding: 2px; text-align: center;">Alkane</div> </div> </div>
	<p><b>ii</b></p> <div> <p style="text-align: center;"> <math display="block">\begin{array}{c} \text{H} &amp; &amp; \text{H} \\ &amp; \diagdown &amp; / \\ &amp; \text{C} = \text{C} \\ &amp; / &amp; \diagdown \\ \text{H} &amp; &amp; \text{H} \end{array} + \text{H}_2\text{O} \xrightarrow[\text{HEAT (300°C \&amp; 60 atm)}]{\text{H}_3\text{PO}_4 \text{ CATALYST}} \begin{array}{c} \text{H} &amp; \text{OH} \\   &amp;   \\ \text{H}-\text{C} &amp; -\text{C}-\text{H} \\   &amp;   \\ \text{H} &amp; \text{H} \end{array}</math> </p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px; text-align: center;">Alkene</div> <div style="text-align: center;">Change in functional group →</div> <div style="border: 1px solid black; padding: 2px; text-align: center;">Alcohol</div> </div> </div>
	<p><b>iii</b></p> <div> <p style="text-align: center;"> <math display="block">\begin{array}{c} \text{H}_3\text{C} &amp; &amp; \text{H} \\ &amp; \diagdown &amp; / \\ &amp; \text{C} = \text{C} \\ &amp; / &amp; \diagdown \\ \text{H} &amp; &amp; \text{H} \end{array} + \text{HBr} \xrightarrow{\text{ROOM TEMP.}} \begin{array}{c} \text{H} &amp; \text{Br} \\   &amp;   \\ \text{H}_3\text{C}-\text{C} &amp; -\text{C}-\text{H} \\   &amp;   \\ \text{H} &amp; \text{H} \end{array} \text{ OR } \begin{array}{c} \text{Br} &amp; \text{H} \\   &amp;   \\ \text{H}_3\text{C}-\text{C} &amp; -\text{C}-\text{H} \\   &amp;   \\ \text{H} &amp; \text{H} \end{array}</math> </p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px; text-align: center;">Alkene</div> <div style="text-align: center;">Change in functional group →</div> <div style="border: 1px solid black; padding: 2px; text-align: center;">Halogenoalkane</div> </div> <p style="text-align: center; margin-top: 10px;"> <span style="margin-right: 100px;">MINOR PRODUCT</span> <span>MAJOR PRODUCT</span> </p> </div> <p>Heterolytic Fission in bond</p>

Dissolved in organic solvent

Heterolytic Fission in bond

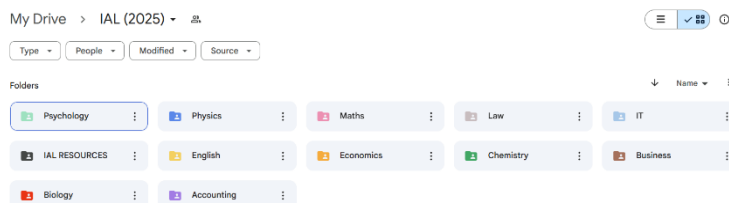
iv	 <p>Alkene → Change in functional group → dihalogenoalkane</p>
v	<p>On top of electrophilic addition reaction, <b>alkenes</b> can also be oxidised by shaking it with cold dilute <math>\text{KMnO}_4</math> (acidified potassium manganate(VII))          Pale purple solution turns colorless (a <b>diol</b> is produced)          This can also be used as a test for alkenes just like bromine water</p>  <p>Alkene → Change in functional group → diol</p>
5.5	<p>know the qualitative test for a <math>\text{C}=\text{C}</math> double bond using bromine or bromine water</p>
	<p><u>Bromine Water Test</u>          Shake the unknown compound to be tested with bromine water in a test tube          If it is unsaturated (has double bonds), addition reaction will occur and the solution will turn from orange to colorless          (A qualitative test shows a yes or no, if its present or not, it doesn't how much it contains)          It's better to know the colors of bromine in different states (orange in solution, red-brown liquid at room temperature and orange vapour)</p>
5.6	<p>be able to describe the mechanism (including diagrams), giving evidence where possible, of:</p> <ol style="list-style-type: none"> <li>the electrophilic addition of bromine and hydrogen bromide to ethene</li> <li>the electrophilic addition of hydrogen bromide to propene</li> </ol> <p><i>Use of the curly arrow notation is expected – the curly arrows should start from either a bond or from a lone pair of electrons.</i></p> <p><i>Knowledge of the relative stability of primary, secondary and tertiary carbocation intermediates is expected.</i></p>
i	 <p>Although <math>\text{Br}_2</math> in itself is non-polar, it can have an induced dipole when it is moved closer to a high electron density <math>\text{C}=\text{C}</math> bond of the alkene</p>

ii	 <p>The diagram illustrates the electrophilic addition of HBr to propene. Propene reacts with HBr to form a secondary carbocation intermediate, which then reacts with Br<sup>-</sup> to form the major product, 2-bromopropane. Alternatively, the secondary carbocation can form a primary carbocation intermediate, which then reacts with Br<sup>-</sup> to form the minor product, 1-bromopropane.</p> <ul style="list-style-type: none"> <li>- HBr is a polar molecule as Br is more electronegative than H, the H atom acts as an electrophile and is attracted to the electron-rich pi bond of propene and accepts a pair of electrons</li> <li>- The Br<sup>-</sup> ion acts as a nucleophile</li> <li>- Secondary carbocations are more stable as there are more electron-releasing alkyl groups attached to the carbon with the positive charge</li> <li>- The major product is formed via the more stable carbocation intermediate</li> <li>- Order of stability for carbocations: Tertiary &gt; Secondary &gt; Primary</li> </ul>
5.7	be able to describe the addition polymerisation of alkenes and draw the repeat unit given the monomer, and vice versa
	<b>Addition polymerization</b> is the reaction in which many monomers containing at least one C=C double bond form long chains of polymers as the only product
5.8	understand how chemists limit the problems caused by polymer disposal by: <ul style="list-style-type: none"> <li>i developing biodegradable polymers</li> <li>ii removing toxic waste gases produced by the incineration of polymers</li> </ul>
i	Biodegradable means it can be broken down by micro-organisms over time. The polyester and polyamide condensation polymers are considered to be biodegradable as they can be broken down using hydrolysis reactions, whereas poly(alkenes) cannot.
ii	The toxic waste gases produced by incineration, such as HCl, can be reacted with a base or carbonate. The base reacts with the acidic HCl, thereby neutralizing it.
	<p><b>Further suggested practicals:</b></p> <ul style="list-style-type: none"> <li>i investigating the difference in reactivity of alkanes and alkenes, including combustion, reaction with bromine water, reaction with acidified potassium manganate(VII)</li> <li>ii preparation of cyclohexene from cyclohexanol</li> <li>iii preparation of limonene from orange peel by steam distillation</li> <li>iv preparation of Perspex® from methyl 2-methylpropenoate</li> </ul>

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